Advisory Circular

AC No.: 20-136A
DATE: mm/dd/yy

Rev 8

Protection of Aircraft Electrical / Electronic Systems Against the Indirect Effects of Lightning

Initiated by: AIR-100

CONTENTS

1. PURPOSE.

a. This advisory circular (AC) is for aircraft manufacturers, modifiers, and foreign regulatory authorities. In it, we at the Federal Aviation Administration (FAA) recommend how you can protect aircraft electrical and electronic systems from the effects of lightning. This AC describes a means, but not the only means, for you to show compliance with the applicable sections of Title 14 of the Code of Federal Regulations (14 CFR) parts 23, 25, 27, 29 and 33 as they pertain to the type or supplemental type certification of your aircraft. This document supplements the information needed to form the basis of certification compliance findings to prevent lightning from affecting aircraft electrical and electronic systems.

b. This AC is not mandatory and does not constitute a regulation. However, if you use the means described in this AC, you must follow it in all important respects.

2. CANCELLATION. AC 20-136, *Protection of Aircraft Electrical / Electronic Systems Against the Indirect Effects of Lightning*, dated March 5, 1990, is cancelled.

3. EQUIPMENT HAZARDS COVERED IN THIS AC.

a. This AC addresses hazards posed by the indirect effects of lightning to electrical and electronic systems and their associated wiring that are installed on, or in, aircraft.

b. The guidance material in this document applies to the certification of aircraft and associated equipment.

c. This AC does not address direct effects such as burning, eroding, and blasting of aircraft structure that lightning would have on an aircraft or its equipment, nor does this AC address fuel ignition hazards. (For information on fuel ignition hazards, see AC 20-53, *Protection of Aircraft Fuel Systems Against Fuel Vapor Ignition Caused By Lightning*.) Also, this AC does not address lightning zoning methods or lightning test requirements, nor methods, and techniques for coverings (fairing, skin, and cowl). Those types of coverings should normally be designed to prevent direct attachment of a lightning strike to the underlying system components. However, if direct attachment to a system component can occur, you will need to assess direct and indirect effects. See appendix **2** of this AC for definitions of *lightning strike* and other terms in this AC.

d. Aircraft electrical and electronic systems or components are sometimes directly exposed to lightning current conducted from the aircraft exterior, such as when lightning strikes an antenna and current flows through its coaxial cable to the equipment connected to the other end of the coaxial cable. Identify those possibilities and eliminate them by modifying the design or addressing them in the certification plan. In this AC, we do not discuss these instances further.

4. STEPS FOR SHOWING COMPLIANCE. The following seven steps describe how you may satisfy the certification requirements for your aircraft's electrical and electronic systems, by demonstrating they are safe from the indirect effects of lightning:

- Identify system lightning criticality using aircraft safety analysis
- Determine the lightning strike zones for the aircraft
- Set the airframe lightning current paths for the zones
- Determine the aircraft internal lightning transient environment
- Set transient control levels (TCL) and equipment transient design levels (ETDL)
- Verify compliance
- Take corrective measures, if needed

a. Identify system lightning criticality using aircraft safety analysis.

(1) You should perform a functional hazard assessment (FHA) to identify all failures and classify them in functional and operational terms. Review the results of the FHA to ensure you have identified all unique indirect effects of lightning, such as common mode failures.

(2) You should identify those systems that perform or contribute to functions whose failure results in catastrophic, hazardous/severe major, or major failure conditions. The failure classifications defined as "minor" and "no safety effect" are not covered in this AC.

(3) ACs containing guidance on how to classify these failure conditions include AC 23.1309-1, *System and Equipment Installations in Part 23 Airplanes*, AC 25.1309-1, *System Design and Analysis*, AC 27-1, *Certification of Normal Category Rotorcraft*, and AC 29-2, *Certification of Transport Category Rotorcraft*. Figure **1** below, lists the failure condition classifications described in paragraph **4a(2)** and their corresponding definitions.

Figure 1. Failure Condition Classifications

Classification	Definition
Catastrophic	Failure conditions that prevent continued safe flight and landing. (For Part 23, the definition for catastrophic is: "failure conditions that are expected to result in multiple fatalities of the occupants, or incapacitation or fatal injury to a flight crewmember normally with the loss of the airplane.")
Hazardous/ Severe-Major	Failure conditions that reduce the aircraft's or the crew's ability to cope with adverse operating conditions that would: • Greatly reduce safety margins or functional abilities; • Cause physical distress or larger workload that could prevent flight crew members from performing their tasks accurately or completely; or • Seriously injure a few occupants.
Major	Failure conditions that reduce the aircraft's or the crew's ability to cope with adverse operating conditions that would, for example: • Significantly reduce safety margins or functional abilities; • Significantly increase crew workload or decrease crew efficiency; or • Cause discomfort to occupants, possibly including injuries.

(4) You should assign the system's lightning assurance level based on the FHA and gain agreement on this assignment from the cognizant aircraft certification office (ACO). See SAE ARP 4754, *Certification Considerations for Highly-Integrated or Complex Aircraft Systems*, for guidance on the assurance level. Figure 2 below, shows the lightning assurance levels related to the failure condition classifications. Redundancy alone cannot protect against the indirect effects of lightning because the electromagnetic fields and structural IR voltages can interact, at the same time, with all electrical wiring aboard an aircraft.

Figure 2. Development Lightning Levels

Lightning Assurance Levels	Failure Condition Classification
Level A	Electrical and electronic systems whose failure would cause or contribute to a *catastrophic* failure condition for the aircraft.
Level B	Electrical and electronic systems whose failure would cause or contribute to a *hazardous/severe-major* failure condition for the aircraft.
Level C	Electrical and electronic systems whose failure would cause or contribute to a *major* failure condition for the aircraft.

b. Determine the Lightning Strike Zones for the Aircraft. Lightning zoning is a functional step in demonstrating the aircraft is adequately protected from both direct and indirect effects of lightning. The purpose of lightning zoning is to determine those surfaces of the aircraft likely to experience lightning channel attachment and those structures that may conduct lightning current between lightning attachment points. As an applicant, you must determine the lightning attachment zones for your aircraft configuration, since the zones will be dependent on the aircraft's geometry, materials, and operational factors. Because of this, lightning attachment zones often vary from one aircraft type to another.

> **NOTE:** AC 20-155, *SAE Documents to Support Aircraft Lightning Protection Certification*, references guidance that you can use in determining the lightning attachment zones for your aircraft.

c. Set the Airframe Lightning Current Paths for the Zones. Zones 1 and 2 define where lightning is likely to attach and, as a result, the entrance and exit points for current flow through the aircraft. By definition, Zone 3 areas carry lightning current flow between direct (or swept stroke) attachment points. Therefore, we accept design and analysis using Zone 3 current levels as the external environment. The external lightning environment is:

- Caused by the lightning flash interacting with the exterior of the aircraft.
- Represented by combined waveforms of the lightning current components at the aircraft surface.

> **NOTE:** AC 20-155, also references guidance that you can use in determining the lightning waveforms and their applications.

d. Determine the Aircraft Internal Lightning Transient Environment.

(1) The aircraft internal lightning environment consists of the transient electromagnetic fields and structural IR voltages produced by lightning current flowing through the aircraft. *Structural IR voltage* is the portion of the induced voltage resulting from the product of the distributed lightning current (I) and the resistance (R) of the aircraft skin or structure. The electromagnetic fields and structural IR voltages produce voltages and currents on interconnecting wiring, which appear at equipment interfaces. Electromagnetic fields in the aircraft may penetrate equipment enclosures and compromise system operation.

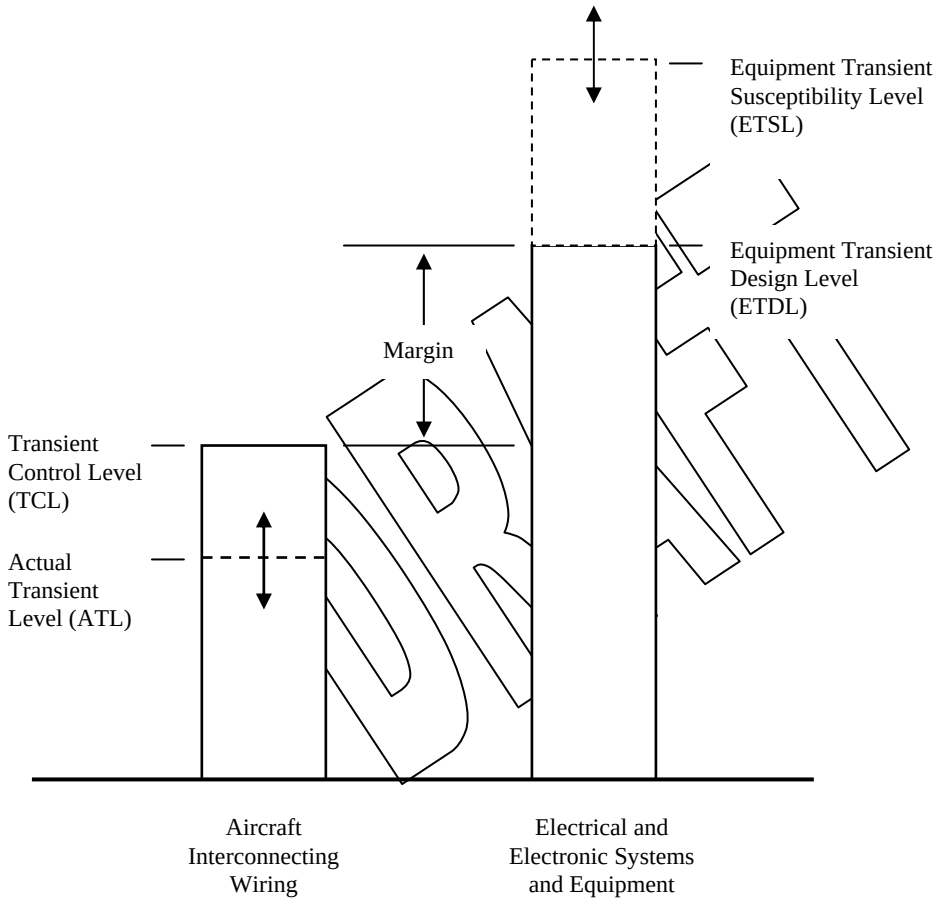
(2) Determine the lightning-induced voltage and current transient waveforms and the actual transient levels (ATL) that can appear at the electrical and electronic equipment interfaces for each system identified in paragraph **4a**. Often, you will define the lightning-induced transients in terms of the open circuit voltage (v_{oc}) and the short circuit current (i_{sc}) appearing at system wiring and equipment interfaces. The voltage and current are dependent on the loop impedances of system interconnecting wiring.

e. Set Transient Control Levels (TCL) and Equipment Transient Design Levels (ETDL).

(1) Specify the ETDL for your electrical and electronic equipment. The ETDL sets a qualification test level for this equipment. The ETDLs represent the amplitude and waveform of voltage or current that the equipment must withstand and remain operational. The equipment transient susceptibility level (ETSL) is the amplitude of voltage or current that, when applied to the equipment, will damage the components or cause an upset that prevents the equipment from performing its intended function.

(2) Specify the TCLs so they are equal to or greater than the maximum expected ATL. The TCLs represent the amplitude and waveforms of voltage and current that the aircraft internal lightning transient environment will produce on system wiring.

Figure 3. Relationships Among Transient Levels



(3) The difference between ETDL and TCL is known as the margin. Figure **3** above, shows the relationship among ATLs, TCLs, ETDLs, and ETSLs. You should evaluate the aircraft, interconnecting wiring, and equipment protection to determine the most effective combination of TCLs and ETDLs that will provide acceptable margin. Appropriate margins to

account for uncertainties in the verification techniques may be required as discussed in paragraph **6** of this AC.

f. Verify Compliance.

(1) Show that the ATLs at wiring and equipment interfaces do not exceed the established TCLs, that the equipment is qualified to the ETDLs, and that the ETDLs exceed the TCLs and ATLs by appropriate margin.

(2) Verification may be accomplished by tests, by analysis, or by demonstrating similarity with previously certified aircraft and systems.

(3) Submit your certification plan early in the program to the cognizant aircraft certification office (ACO) for their review. Experience shows, particularly with aircraft using new technology or those that have complex systems, that early agreement on the certification plan benefits both the applicant and the cognizant ACO. The plan should define acceptable ways to resolve critical issues during the certification process. Analysis and test results during the certification process may warrant modifications in the design or verification methods. When significant changes are necessary, update the certification plan accordingly. The plan may include the items listed in figure **4**:

Figure 4. Items to Include in Certification Plan

ITEM	DISCUSSION
Description of systems	Describe systems' installation, including unusual or unique features; the operational aspects; lightning attachment zones; lightning environment; and preliminary estimate of ETDLs and TCLs.
Description of compliance method	Describe how to verify compliance. Typically, your verification method includes similarity, analytical procedures, and tests. If using analytical procedures, describe how to verify them. For more information, see paragraph **7d** of this AC.
Acceptance criteria	Determine the acceptance criteria for each system by analyzing how safe the system is. During this safety analysis, assess the aircraft in its various operational states; account for the failure and disruption modes caused by the indirect effects of lightning.
Test plans	Plan each test you include as part of your certification process. As an applicant, you can decide if your test plans are separate documents or part of the compliance plan. Your test plans should state the test sequence.

g. Take Corrective Measures. When tests and analyses show that the system did not meet the acceptance criteria, review the aircraft, installation or system design, and improve protection against lightning.

5. EFFECTS OF INDUCED TRANSIENTS. Lightning can induce voltage and current transients on equipment circuits. Equipment circuit impedances and configurations will help determine whether induced transients are mostly voltage or current. These transient voltages and currents can degrade system performance permanently or temporarily. The two primary types of degradation are:

a. Component Damage. This is a permanent condition in which transients alter the electrical characteristics of a circuit. Devices that may be susceptible to component damage are:

- Active electronic devices, especially high frequency transistors, integrated circuits, microwave diodes, and power supply components;
- Passive electrical and electronic components, especially those of very low power or voltage rating;
- Electro-explosive devices, such as squibs and detonators;
- Electromechanical devices, such as indicators, actuators, relays, and motors; and
- Insulating materials (for example, insulating materials in printed circuit boards and connectors) and electrical connections that can burn or melt.

b. System Functional Upset.

(1) Functional upset is mainly a system problem, caused by electrical transients. It may permanently or momentarily upset a signal, circuit, or a system component. This can adversely affect system performance enough to compromise flight safety. A functional upset is a change in digital or analog state that may or may not require manual reset. In general, functional upset depends on circuit design and operating voltages, signal characteristics and timing, and system and software configuration.

(2) Systems or devices that may be susceptible to functional upset include:

- Computers and data/signal processing systems;
- Electronic engine and flight controls; and
- Power generating and distribution systems.

6. MARGINS AND VERIFICATION METHODS. Margins account for uncertainty in the verification process. As confidence in the verification method increases, the margin can decrease. The magnitude of the margin is also directly proportional to the degree that each system contributes to aircraft safety as determined by the aircraft safety analysis. An acceptable margin is essential to the compliance process.

7. LEVEL A SYSTEM LIGHTNING CERTIFICATION.

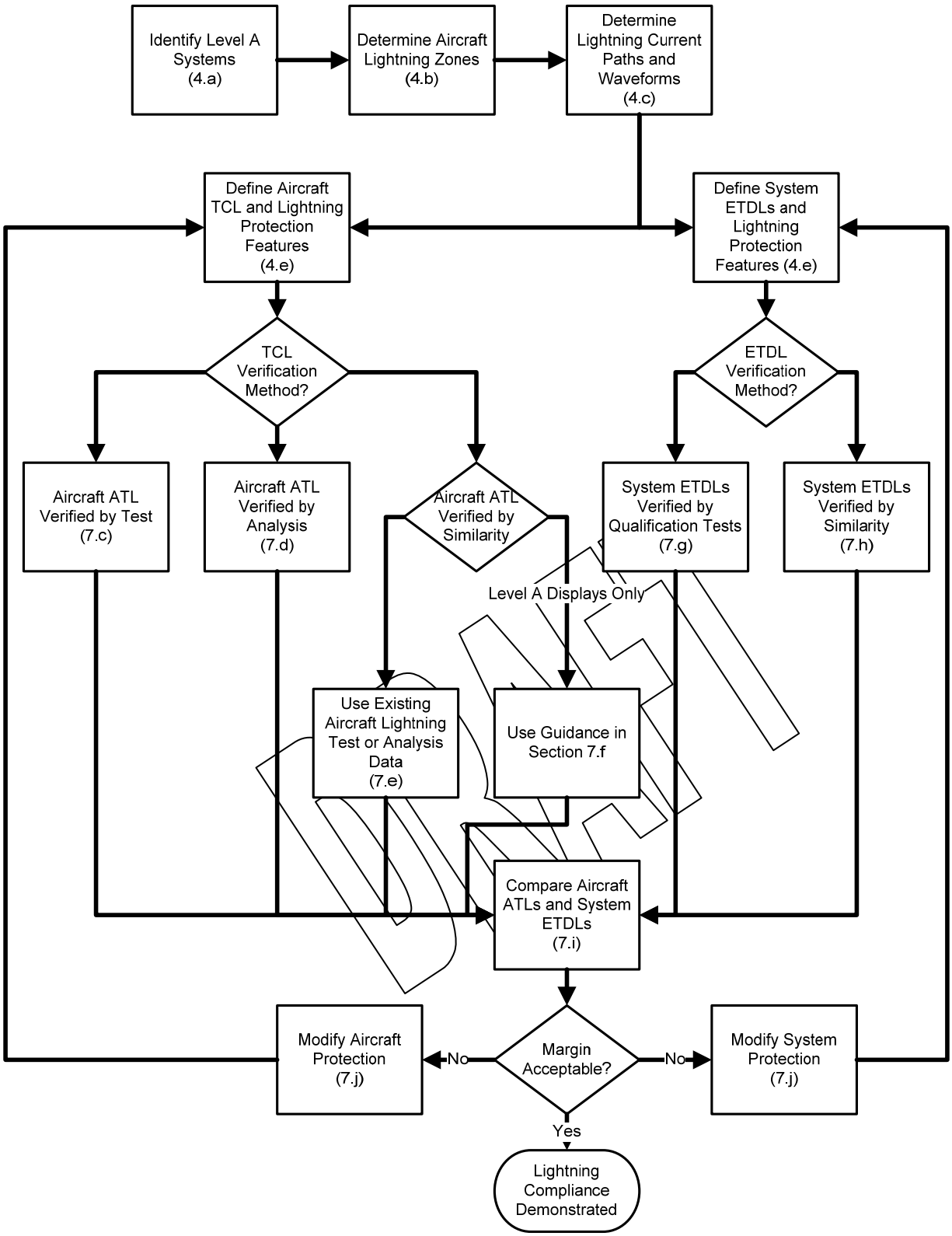
a. Identify Level A Systems.

(1) As an applicant, you must identify Level A systems as described in paragraph **4a**.

(2) Figure **5** below, presents a process that you can use to show that your Level A system complies with 14 CFR requirements.

(3) Define the detailed system performance pass/fail criteria. Before testing or analyzing Level A systems get your regulatory authority to agree to the criteria.

Figure 5. Typical Iterative Process for Level A Systems



b. Set TCLs and ETDLs. You may use existing aircraft data from tests and analyses to set TCLs and ETDLs.

c. Determine ATLs Using Aircraft Tests. You may use aircraft tests to determine the ATLs. See SAE ARP 5415, *User's Manual for Certification of Aircraft Electrical/Electronic Systems Against the Indirect Effects of Lightning*, for guidance on how to test aircraft to determine the ATLs.

d. Determine ATLs Using Analysis. You may use aircraft analysis to determine the ATLs. See SAE ARP 5415 for guidance on how to analyze aircraft to determine the ATLs. Analysis techniques are available that calculate lightning transients using analytical models of the entire aircraft including the internal structure and wires. Acceptance of the analysis method you choose depends on the accuracy of the method. You should confirm your analysis method accuracy using experimental data, and gain agreement with your analysis approach from the cognizant aircraft certification office.

e. Determine ATLs Using Similarity.

(1) You may use similarity to determine the ATLs. You may do this when there are:

- Only minor differences between the previously certified aircraft and system installation, and the aircraft and system installation to be certified; and
- There are no unresolved in-service history of problems related to lightning strikes to the previously certified aircraft.

(2) If you are unsure how the differences will affect the aircraft ATLs, perform more tests and analyses to resolve the open issues.

(3) To use similarity, you must assess the aircraft, wiring, and system installation differences that can adversely affect the system susceptibility. When assessing a new installation, consider differences that affect the internal lightning environment of the aircraft and its effects on the system. The assessment should cover:

- Aircraft type, equipment locations, airframe construction, structural materials, and apertures that could affect attenuation of the external lightning environment;
- System wiring size and routing, wire types (whether parallel or twisted wires), connectors, and wire shielding;
- Grounding and bonding.

(4) You cannot use similarity for a new aircraft design with new systems.

f. Determine ATLs Using RTCA/DO-160 Section 22 Guidance (Level A Displays Only).

(1) This approach is only applicable to Level A display systems. Level A displays involve functions for which the pilot will be within the loop through pilot/system information exchange. The reason that this approach should not be used for other Level A systems, such as control systems, is because failures and malfunctions of those systems can more directly and abruptly contribute to a catastrophic failure event than display system failures and malfunctions; therefore, other Level A systems require a more rigorous lightning transient compliance verification program.

(2) You must use the information in figure **6** to evaluate your aircraft and system installation features to select an appropriate ETDL for your system. You must provide the cognizant ACO with a description of your aircraft and system installation features and compare these to the information in figure **6** to substantiate the ETDL selected for your aircraft and Level A display system installation.

(3) This approach offers a means of selecting the ETDLs for your Level A display system without determining specific aircraft ATLs through test or analysis. RTCA/DO-160E, Section 22, Tables 22-2 and 22-3, provides levels that may be selected as ETDLs.

Figure 6. Equipment Transient Design Levels

RTCA/DO-160 SECTION 22 LEVEL	EXPLANATION
Level 5	Use this level when the equipment under consideration (or the wire bundle or interfaces to and from the equipment) is in *very severe* electromagnetic environments. We at the FAA define these environments as: • Areas with composite materials whose shielding is not very effective; • Areas where there is no guarantee of structural bonding; and • Other open areas where there is little shielding. You can also use this level to cover a broad range of installations. You may need higher ETDLs when there are high current density regions on mixed conductivity structures (such as wing tips, engine nacelle fin, and so on) because the wiring may divert some of the lightning current. If you are the system designer, apply measures to reduce the need for higher ETDLs.
Level 4	Use this level when the equipment under consideration (or the wire bundle or interfaces to and from the equipment) is in *severe* electromagnetic areas. We define these environments as areas outside the fuselage (such as wings, fairings, wheel wells, pylons, control surfaces, and so on).
Level 3	Use this level when the equipment under consideration, all interfaces to and from the equipment, and the wire bundle are entirely in a *moderate* electromagnetic environment. We define this environment as the inside of a metallic or composite aircraft structure – whose shielding is as effective, without improvements. Examples of such an environment are avionics bays not enclosed by bulkheads, cockpit areas, and locations with large apertures (that is, doors without electromagnetic interference (EMI) gaskets, windows, access panels, and so on). Current-carrying conductors in this environment (such as hydraulic tubing, control cables, wire bundles, metal wire trays, and so on) are not necessarily electrically grounded at bulkheads. When few wires exit the environment, either use a higher level (that is, *Level 4* or *5*) for these interfaces or offer more protection for these wires.
Level 2	Use this level when the equipment under consideration, all interfaces to and from the equipment, and the wire bundle are entirely in a *partially protected* environment. We define this environment as the inside of a metallic or composite aircraft structure – whose shielding is as effective, if you take measures to reduce the electromagnetic coupling on wires. Wire bundles in this environment pass through bulkheads, and have shields that end at the bulkhead connector. When a few wires exit the environment, use either a higher level (that is, *Level 3* or *4*) or provide more protection for these wires. Install wire bundles close to the ground plane, to take advantage of other inherent shielding from metallic structures. Current-carrying conductors (such as hydraulic tubing, control cables, metal wire trays, and so on) are electrically grounded at all bulkheads.
Level 1	Use this level when the equipment under consideration, all interfaces to and from

RTCA/DO-160 SECTION 22 LEVEL	EXPLANATION
	equipment, and the wire bundles are entirely in a *well-protected* environment. We define this environment as an electromagnetically enclosed area on which lightning strikes will not directly attach.

g. Verify System ETDLs Using System Qualification Tests.

(1) Verify the ETDLs for single stroke, multiple stroke, and multiple burst testing. Test the system using single stroke, multiple stroke, and multiple burst wire bundle testing waveform sets as prescribed in RTCA/DO-160E, Section 22, using test levels that equal to or greater than the defined ETDLs for the system. Show that the system operates within the defined acceptance criteria during these tests. Test the equipment using single stroke pin injection testing as prescribed in RTCA/DO-160E, Section 22 and EUROCAE ED-14E. Show that the equipment can withstand the ETDLs without damage.

(2) Evaluate any system effects observed during the qualification tests to ensure these do not adversely affect the system's continued performance. The cognizant aircraft certification office must approve your evaluation.

h. Verify System ETDLs Using Existing System Data (Similarity).

(1) You may base your ETDL verification on similarity to previously certified systems without performing more tests. You may do this when there are:

- Only minor differences between the previously certified system and installation, and the system and installation to be certified; and
- There are no unresolved in-service system problems related to lightning strikes on the previously certified system.
- The previously certified system ETDLs were verified by qualification tests.

(2) If you are unsure how the differences will affect the systems and installations, you must perform more tests and analyses to resolve the open issues.

(3) To use similarity, you must assess differences between the previously certified system and installation and the system and installation to be certified that can adversely affect the system susceptibility. The assessment should cover:

- System interfaces, wiring size and routing, connectors (whether parallel or twisted wires), and wire shielding;
- Grounding and bonding; and
- System software, firmware, and hardware.

(4) You must assess every system, even if it uses equipment and installation techniques that have previous certification approval.

(5) You cannot use similarity for a new aircraft design with new systems.

i. Verify Compliance. You must compare the verified system ETDLs with the aircraft ATLs and determine if acceptable margin exists between the ETDLs and ATLs. Margins account for uncertainty in the verification method. As confidence in the verification method increases, the margin can decrease. An ETDL that exceeds the ATL by a factor of two is an acceptable margin for Level A systems, if this margin is verified by aircraft test or by analysis supported by aircraft tests. For other verification methods, the margin should be agreed upon with the cognizant ACO.

j. Corrective Measures.

(1) When your system fails to meet the certification requirements, you must decide on corrective actions. The changes or modifications you make to the system or the equipment may require more testing and analysis.

(2) To meet the certification requirements, you may need to repeat equipment qualification testing, or aircraft testing and analysis (in whole or in part). You also may need to modify the equipment or installation to get certification.

8. LEVEL B AND C SYSTEM LIGHTNING CERTIFICATION.

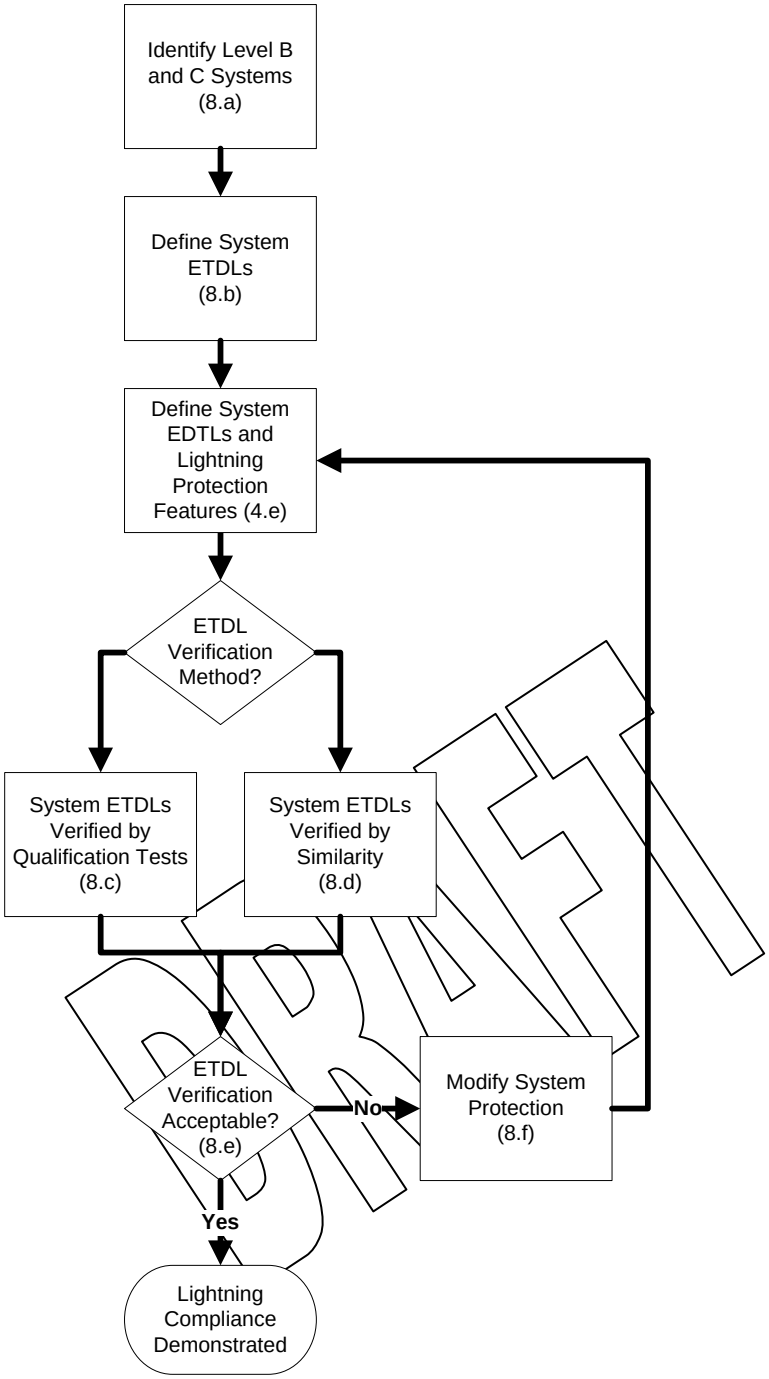
a. Identify Level B and C Systems.

(1) As an applicant, you must identify Level B and C systems as described in paragraph **4a**.

(2) Define the detailed system performance pass/fail criteria. Before testing or analyzing Level B and C systems, get your regulatory authority to agree to the criteria.

(3) Figure **7** below, presents a process you can use to show that your Level B and C system complies with 14 CFR requirements.

Figure 7. Typical Iterative Process for Level B and C Systems



b. Set ETDLs.

(1) You may use the ATLs determined during aircraft tests or analyses performed for Level A systems to select appropriate ETDLs for Level B and C systems.

(2) Alternatively, you may use the definitions in RTCA/DO-160E, Section 22 to select appropriate ETDLS for Level B and C systems.

- Use RTCA/DO-160E, Section 22 Level 3 for most Level B systems.
- For Level B systems and associated wiring installed in more severe electromagnetic environments, use RTCA/DO-160E, Section 22 Level 4 or 5 as appropriate to the environment. Examples of more severe electromagnetic environments include areas external to the fuselage, areas with composite structures showing poor shielding effectiveness, and other open areas.
- Use RTCA/DO-160E, Section 22 Level 2 for most Level C systems.
- For Level C systems installed in more severe electromagnetic environments, use RTCA/DO-160E, Section 22 Level 3. Examples of more severe electromagnetic environments include areas external to the fuselage, areas with composite structures showing poor shielding effectiveness, and other open areas.
- You must provide the cognizant ACO with a description of your aircraft and system installation features to substantiate the RTCA/DO-160E, Section 22 levels selected for your system.

(3) If you are an installer and you install a group of Level C systems in more severe electromagnetic environments, your FHA should consider the consequence of the group's simultaneous failure resulting from a lightning strike. If you classify that group's combined failure as ***hazardous/severe-major***, then select the ETDL of Level C systems in that group as if they were Level B systems.

c. Verify System ETDLs Using Equipment Qualification Tests.

(1) Verify the ETDLs for single stroke testing. Test the equipment using single stroke testing waveform sets as prescribed in RTCA/DO-160E, Section 22, using test levels that are equal to or greater than the defined ETDLs for the system. Show that the equipment operates within the defined acceptance criteria during these tests. Test the equipment using single stroke pin injection testing as prescribed in RTCA/DO-160E, Section 22 and EUROCAE ED-14E. Show that the equipment can withstand the ETDLs without damage.

(2) Evaluate any equipment effects observed during the qualification tests to ensure these do not adversely affect the system's continued performance. The cognizant aircraft certification office must approve your evaluation.

(3) Level B and C systems do not require multiple lightning strike and multiple burst tests in RTCA/DO-160E Section 22.

d. Verify System ETDLs Using Existing Equipment Data (Similarity).

(1) You may verify ETDL by similarity to previously certified systems without performing more tests. You may do this when there are:

- Only minor differences between the previously certified system and installation, and the system and installation to be certified; and
- There are no unresolved in-service system problems related to lightning strikes on the previously certified system.
- The previously certified system ETDLs were verified by qualification tests.

(2) If you are unsure how the differences will affect the systems and installations, you must perform more tests and analyses to resolve the open issues.

(3) To use similarity, you must assess differences between the previously certified system and installation and the system and installation to be certified that can adversely affect the system susceptibility. The assessment should cover:

- Equipment interfaces, wiring size and routing, connectors (whether parallel or twisted wires), and wire shielding;
- Grounding and bonding; and
- Equipment software, firmware, and hardware.

e. Verify Compliance. You must show that the Level B and C systems meet their defined acceptance criteria during the qualification tests at the selected system ETDLs.

f. Take Corrective Measures. When your system fails to meet the certification requirements, you must decide on corrective actions. If you change or modify the system or installation, you may need to repeat equipment qualification testing.

9. MAINTENANCE AND SURVEILLANCE.

a. In the Instructions for Continued Airworthiness (ICA) (for example, 14 CFR § 25.1529), you must identify the minimum maintenance required to support certification. Some systems or equipment in an installation require dedicated protection devices, or specific techniques to protect them. You should define the requirements for periodic and conditional maintenance and surveillance of these devices or techniques, to ensure the protection do not degrade while the system or equipment is in service. Avoid using – or identify when to replace – devices that may degrade with time because of corrosion, fretting, flexing cycles, or other causes.

b. Evaluate how modifications to the aircraft or system will be affected against the direct and indirect effects of lightning. In principle, base this assessment on analysis or measurement.

c. You should define the techniques and time needed to determine whether the system continues to protect against lightning. Also, identify built-in test equipment, resistance measurements, continuity checks of the entire system, or other means to determine your system's integrity periodically and conditionally.

d. See SAE ARP 5415 for more information on aircraft lightning protection maintenance and surveillance.

David W. Hempe
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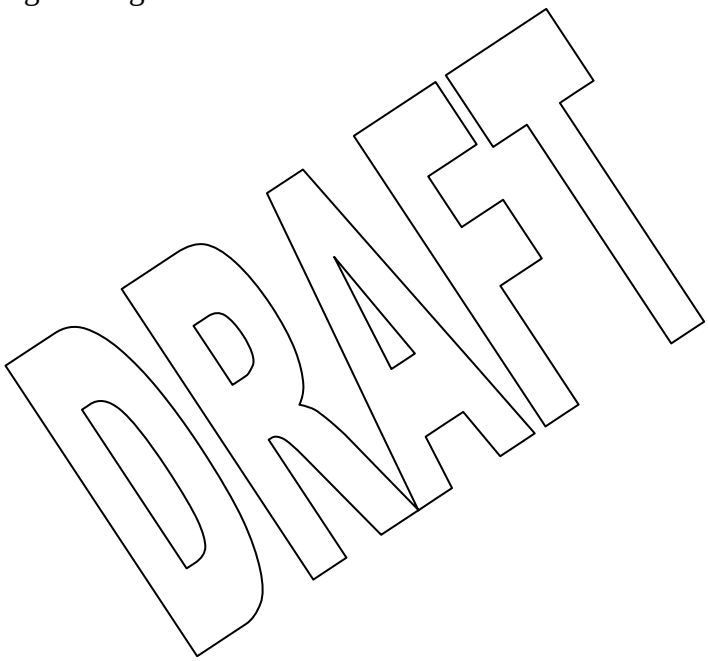

APPENDIX 1. RELATED DOCUMENTS AND HOW TO GET THEM

1. Title 14 of the Code of Federal Regulations (14 CFR). You can get copies of the following 14 CFR sections from the Superintendent of Documents, Government Printing Office, Washington, D.C. 20402-9325. Telephone 202-512-1800, fax 202-512-2250. You can also get copies from the Government Printing Office (GPO), electronic CFR Internet website at www.access.gpo.gov/ecfr/.

a. Part 23, Airworthiness Standards: Normal, Utility, Acrobatic, and Commuter Category Airplanes:

§ 23.901 Power plant; installation
§ 23.1301 Function and installation
§ 23.1309 Equipment, systems, and installations
§ 23.1529 Instructions for continued airworthiness

b. Part 25, Airworthiness Standards: Transport Category Airplanes:

§ 25.901 Power plant; installation
§ 25.1301 Function and installation
§ 25.1309 Equipment, systems, and installations
§ 25.1316 System lightning protection
§ 25.1529 Instructions for continued airworthiness

c. Part 27, Airworthiness Standards: Normal Category Rotorcraft:

§ 27.901 Power plant; installation
§ 27.1301 Function and installation
§ 27.1309 Equipment, systems, and installations
§ 27.1529 Instructions for continued airworthiness

d. Part 29, Airworthiness Standards: Transport Category Rotorcraft:

§ 29.901 Power plant; installation
§ 29.1301 Function and installation
§ 29.1309 Equipment, systems, and installations
§ 29.1529 Instructions for continued airworthiness

e. Part 33, Airworthiness Standards: Aircraft Engines:

§ 33.28 Electrical and electronic engine control systems
§ 33.53 Engine component tests (*Reciprocating aircraft engines*)
§ 33.91 Engine component tests (*Turbine aircraft engines*)

2. FAA Advisory Circulars (AC). You can get copies of the following ACs from the U.S. Department of Transportation, Subsequent Distribution Office, M-30, Ardmore East Business Center, 3341 Q 75th Avenue, Landover, MD 20795. Telephone 301-322-5377,

APPENDIX 1. RELATED DOCUMENTS (continued)

fax 301-386-5394. You can also get copies from our Regulatory and Guidance library (RGL) at www.airweb.faa.gov/rgl. On the RGL website, select "Advisory Circulars," then select "By Number."

a. AC 20-155, SAE Documents to Support Aircraft Lightning Protection Certification.

b. AC 21-16, Radio Technical Commission for Aeronautics Document DO-160E.

c. AC 23.1309-1, System and Equipment Installations in Part 23 Airplanes.

d. AC 25.1309-1, System Design and Analysis.

e. AC 27-1, Certification of Normal Category Rotorcraft.

f. AC 29-2, Certification of Transport Category Rotorcraft.

3. Industry Documents.

a. European Organization for Civil Aviation Equipment (EUROCAE) Documents. You can get copies of EUROCAE ED-14E, Environmental Conditions and Test Procedures for Airborne Equipment, dated March 2005, from EUROCAE, 17 rue Hamelin, 75116 Paris, France. Telephone 33 (0) 1 4505 7188, fax 33 (0) 1 4505 7230, website www.eurocae.org.

b. RTCA Document. You can get copies of RTCA/DO-160E, Environmental Conditions and Test Procedures for Airborne Equipment, dated December 9, 2004, from RTCA, Inc., 1828 L Street, NW, Suite 805, Washington, DC 20036. Telephone 202-833-9339, fax 202-833-9434, website www.rtca.org.

c. Society of Automotive Engineers (SAE) Documents. You can get copies of the following documents from SAE World Headquarters, 400 Commonwealth Drive, Warrendale, PA 15096-0001. Telephone 724-776-4970, fax 724-776-0790, website www.sae.org.

(1) Aerospace Recommended Practice (ARP) 4754, Certification Considerations for Highly Integrated or Complex Aircraft Systems, dated November 1996.

(2) ARP5415A, User's Manual for Certification of Aircraft Electrical/Electronic Systems Against the Indirect Effects of Lightning, May 2002.

APPENDIX 2. DEFINITIONS

The following definitions apply to this AC:

TERM	DEFINITION
Actual Transient Level (ATL)	The level of transient voltage or current that appears at the equipment interfaces because of the external environment. This level may be less than or equal to the transient control level, but should not be greater.
Aperture	An electromagnetically transparent opening.
Attachment Point	A point where the lightning flash contacts the aircraft.
Component Damage	A condition in which transients permanently alter the electrical characteristics of a circuit. Because of this, the component can no longer perform to its specifications.
Continued Safe Flight and Landing	The aircraft can safely abort or continue a takeoff, or continue controlled flight and landing, possibly using emergency procedures. The aircraft must do this without requiring exceptional pilot skill or strength. Some aircraft damage may occur because of the failure condition or on landing. For transport airplanes, the pilot must be able to land safely at a suitable airport. For Part 23 airplanes, it is not necessary to land at an airport. For rotorcraft, the rotorcraft must continue to cope with adverse operating conditions, and the pilot must be able to land safely at a suitable site.
Direct Effects	Physical damage to the aircraft or electrical and electronic systems. Direct attachment of lightning to the system's hardware or components causes the damage. Examples of direct effects include tearing, bending, burning, vaporization, or blasting of aircraft surfaces and structures, and damage to electrical and electronic systems.
Display Systems	Flight, navigation, and power plant instruments required by 14 CFR §§ xx.1303 and xx.1305.
Equipment Interface	A location on an equipment boundary where connection is made to the other components of the system of which it is part. It may be an individual wire connection to an electrical or electronic item, or wire bundles that interconnect equipment. It is at the equipment interface that the equipment transient design level and transient control level are defined, and where the actual transient level should be identified.
Equipment Transient Design Level (ETDL)	The peak amplitude of transients to which you qualify your equipment.

APPENDIX 2. DEFINITIONS (continued)

TERM	DEFINITION
Equipment Transient Susceptibility Level (ETSL)	The peak amplitude of transients that will damage or upset the system components.
External Environment	The natural lightning environment, outside the aircraft, for design and certification purposes. See AC 20-155, which references documents that provide additional guidance on aircraft lightning environment and related waveforms.
Indirect Effects	Electrical transients induced by lightning in aircraft electrical or electronic circuits.
Internal Environment	The potential fields and structural IR voltages inside the aircraft produced by the external environment.
Lightning Flash	The total lightning event. It may occur in a cloud, among clouds, or between a cloud and the ground. It can consist of one or more return strokes, plus intermediate or continuing currents.
Lightning Strike	Attachment of the lightning flash to the aircraft.
Lightning Strike Zones	Aircraft surface areas and structures that are susceptible to lightning attachment, dwell time, and current conduction. See AC 20-155, which references documents that provide additional guidance on aircraft lightning zoning.
Lightning Stroke (Return Stroke)	A lightning current surge that occurs when the lightning leader (the initial current charge) makes contact with the ground or another charge center, A charge center is an area of high potential of opposite charge.
Margin	The difference between the equipment transient design level and the transient control level.
Multiple Burst	A randomly spaced series of bursts of short duration, low amplitude current pulses, with each pulse characterized by rapidly changing currents (that is, high di/dt). These bursts may result as the lightning leader progresses or branches, and are associated with the cloud-to-cloud and intra-cloud flashes. The multiple bursts appear most intense when the initial leader attaches to the aircraft. See AC 20-155.
Multiple Stroke	Two or more lightning return strokes during a single lightning flash. See AC 20-155.
Return Stroke	see *Lightning Stroke*

APPENDIX 2. DEFINITIONS (continued)

TERM	DEFINITION
Structural IR Voltage	The portion of the induced voltage resulting from the product of the distributed lightning current (I) and the resistance (R) of the aircraft skin or structure.
Swept Channel	The path lightning travels. Because of the aircraft's motion, the lightning flash causes successive attachments as it sweeps across the aircraft.
System Functional Upset	A permanent or momentary problem that affects how the system performs (for example, a change of digital or analog state). Electrical transients cause these problems. Upsets may or may not require manual reset.
Transient Control Level (TCL)	The maximum allowable level of transients that appear at the equipment interfaces because of the defined external environment.
Upset	see *System Functional Upset*

APPENDIX 3. ACRONYMS

We use the following acronyms throughout this AC:

AC	Advisory Circular
ACO	Aircraft Certification Office
AFM	Airplane Flight Manual
ARP	Aerospace Recommended Practice
ATL	Actual Transient Level
CFR	Code of Federal Regulations
ETDL	Equipment Transient Design Level
ETSL	Equipment Transient Susceptibility Level
FAA	Federal Aviation Administration
FHA	Functional Hazard Assessment
i_{sc}	Short Circuit Current
IR	Current (I) x Resistance (R)
SAE	Society of Automotive Engineers
TCL	Transient Control Level
v_{oc}	Open Circuit Voltage